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The influence of target size, peripheral target position, and viewing distance on target detection and identification was studied. Thirteen normally-sighted males were trained, and then replicated seven complete task performances. The main effects of target size, target position, and viewing distance were all highly significant, as were the involved simple and second-order interactions ($p < .001$). Both viewing distance and target size significantly influenced target detection, in inverse relation to the effective size of the stimulus, such that reduced image size at the eye was associated with longer target detection time.

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The degree of peripheral target location was universally associated with longer detection time for all target sizes, indicating that search performance was strongly oriented to the center of the field of view, rather than to the periphery. This coorobroates previous findings regarding central peripheral response time relationships. This study is unusual in combining laboratory control of stimulus and viewing conditions with the use of realistic target objects usually obtainable only in field studies.

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Size, Distance, and Peripheral Position Effects on Target Detection

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1. Introduction

Prompt and accurate detection of target objects in the field of view is a vital requirement of many operational tasks, both military and civilian. In a previous study, we were able to show (Kobrick, 1976) that capability for detection of military targets in a field situation was directly related to the viewing distance, and to the degree of peripheral displacement of the targets from a central line of sight. These results are in agreement with a variety of published findings of reduced visual performance efficiency in the periphery compared to foveal capability (Cohan & Haith 1977, Haines 1973 (a)(b), Held 1970, Kerr 1971, Kobrick 1965, Leibowitz 1973, Mackworth 1965, Sanders 1966, Schneider 1969). We also showed that target detection was significantly impaired during exposure to hypoxia conditions, as compared to the same performance at sea level. This finding is consistent with other reports of hypoxic impairments of both central and peripheral visual performance (Birren et al. 1946, Hecht et al. 1946, Kobrick 1971, 1972, 1974, 1975, Kobrick and Appleton 1971, Tune 1964). In our 1976 study, the targets were presented as a series of projected slides containing a soldier in rifle-firing position, viewed against a background of trees and brush. In the series, the soldier target was shown both centrally and at various peripheral positions in the visual field, and at different viewing distances. All targets were presented so as to duplicate their equivalent real-world image sizes.

This task could be practically useful in the study of target detection and more general visual search, since it sensitively reflected the effects of peripheral target position, viewing distance, and hypoxia exposure. Furthermore, the task was fairly realistic since it was presented in the context of an imaginable combat situation. However, the viewing situation contained some corrupting factors which were not initially apparent. First, various segments of the natural background were widely different in color, brightness, and contrast, resulting in inherently easier target detection at some locations than at others. Second, use of the same target object in all cases probably resulted in an increasing familiarity with it through the course of task performance, and, thus, an unrealistic change in its probability of detection. Third, the field upon which the slides were photographed sloped moderately upward away from the background, conferring some advantage for target detection at the farthest viewing distances due to the increased elevation factor. Fourth, since only one target object was used, the absolute effect of target size on detectability could not be assessed.

In order to correct these deficiencies, a new target detection task was developed using a variety of targets, rather than one, and a more uniform background. This paper presents the results of a study to test the capability of this new task for assessing target detection, and discusses more general implications for visual search.

2. Method

2.1. Subjects

Thirteen healthy male soldier volunteers, ages 18-35, were employed. They were initially screened for normal visual acuity (20/20 Snellen, correctible) and depth perception, as well as for any medical abnormalities which might be aggravated by hypoxia. Each subject signed a certificate of voluntary informed consent to participate.

2.2. Apparatus and Procedure

The experimental task involved viewing a series of 35 mm color slides (Ektachrome-X) projected one at a time at 30-second intervals on a large lenticular screen. The slides were photographs of authentic 1/35-scale models of 5 U.S. military objects (Sheridan tank, 2-1/2-ton truck, M-1966 armored personnel carrier, 1/4-ton "jeep" truck, infantry soldier with M-16 rifle). Models were used for purposes of practical convenience, ease of manipulation, and availability. These objects were selected to encompass a range of target sizes likely to be encountered in actual military operations. Each target object was photographed in all combinations of 5 positions in the visual field of the observer (center, 10° right, 20° right, 10° left, 20° left), and 3 viewing distances (60, 90, 120 yards, equivalent). The targets each appeared against a backdrop of standard US Army camouflage cloth, which also covered the horizontal surface upon which they were placed. This cloth contained a variegated but repeating pattern of irregular black, dark green, olive green, and tan areas with approximately the same overall brightness levels as the models.

The 75 target slides were presented in randomized order of occurrence, and were randomly interspersed with 15 slides containing only the background (5 for each viewing distance). The purpose of the "no-target" slides was to allow the opportunity for false-positive responses associated with each target at each viewing distance, and to determine the time for deciding that no target was present. The subject viewed the slides at an appropriate distance such that the visual angle at the eye subtended by each target image was the same as would be the case for the object in the real world viewed at the actual distance involved. Each subject was trained to search each scene when it appeared, and to call out the identity and location of each target as soon as it was recognized. A millisecond-timer was activated at the onset of each slide, and was stopped by a voice-operated relay, connected to a throat microphone worn by the subject, when he spoke each target response.

After the subjects were instructed and trained in performance of the experimental task, each individual completed a preliminary practice session and 2 complete performance sessions on each of 2 successive days at a sea-level location. On the following day, they were transported by aircraft and then by automobile to a high-altitude field laboratory at the summit of Pikes Peak, Colorado, USA (4420 m elevation). Each individual then completed one performance session daily for the following five successive days.

3. Results and Discussion

The basic datum used for analysis of the results was the response time (RT) intervening between the onset of each slide and the activation of the voice-operated relay by the subject. A one-way analysis of variance based on the subject RT's was first performed to determine if hypoxia exposure had any influence on target detection. The results of this analysis showed that neither the hypoxia main effect nor any of the simple interactions of hypoxia with the other design dimensions were statistically significant. Since hypoxia exposure as experienced in this study had no measured influence on target detection performance, the data were then pooled across test days into one combined matrix. These data were then analyzed by an overall treatments-by-subjects multivariate analysis of variance to determine the effects of dimensions of the task itself on target detection performance; i.e., target size (T), target position (P), and viewing distance (D). Based on the subject mean square interactions, the T, P, and D main effects and their simple and second-order interactions all proved highly significant ($P < .001$).

In order to describe the trends in performance represented by the significant main effects, the group mean RT's associated with the various targets, positions, and viewing distances were calculated, and are presented graphically in Figures 1 and 2.

Figures 1 and 2 about here

In Figure 1, the overall group mean RT's averaged across all targets are presented for each target position as a function of each viewing distance. It is clear that the more peripheral targets were consistently more difficult to detect at all viewing distances, even though the maximum of 20^{o} displacement used in this study represents only a moderate excursion into the periphery of the functional visual field. One might expect even larger RT increases with peripheral target positions beyond 20^{o}. The strong effect of viewing distance is also quite evident, in that RT's for targets at all positions increased systematically with extended distance. The irregularity at the center target position for the 60-yard viewing distance was traced to an imperfection in the slide containing the soldier target at that distance, which had the appearance of another soldier. This inconsistency confused the subjects and increased their

RT's to that slide, which in turn increased the group mean RT represented by that data point.

In Figure 2, the overall group mean RT's are shown for each type of target averaged across target position for each viewing distance. The target types have been arbitrarily arrayed along the abscissa in order of increasing size, preceded by the RT's for the blank ("no-target") slides. Since the curves for all viewing distances show systematic and comparable decreases in RT in direct relation to increase in target size, the sheer area of the target must have been the critical factor in target detection. The data are quite consistent as evidenced by the slight differences between APC, tank, and truck RT's, which correctly reflect small differences in size and configuration among those three vehicles. The RT's to blank slides containing no target were the longest in all cases, indicating that the subjects took more time to decide about the absence than they did about the presence of a target. The three curves once again display the marked influence of viewing distance on target detection for all target sizes and, in fact, show larger differences due to distance for the smaller targets, as one might expect.

In the present task, visual qualities such as monocular cues to depth, figure-background configurational relationships, and variations in contrast of target with background, were deliberately minimized while still providing considerably more visual texture than would be experienced with silhouettes. Furthermore, it would seem fair to assume that factors related to perceived distance were minimal, since the irregular pattern of the camouflage cloth used as the background field would have provided few, if any, recognizable familiar cues to relative distance or depth. Thus, any relationship that distance or depth estimation may have had on target detection performance would probably have been slight. Under these circumstances, the data indicate that the principal factor governing the detectability of a target was its virtual size, probably best described as the equivalent image size which the target subtended at the eye, as determined by combinations of target sizes and linear viewing distances.

The size factor was further qualified by the peripheral position of the target in the visual field, in direct relation to its degree of excursion from the central line of sight. This was a general effect, since it occurred at all three viewing distances and, in fact, increased with longer distances.

In summary, this task appears to be a promising approach to the study of target detection throughout the visual field. It has several advantages for study of environmental stress effects under conditions of chamber simulation, since it can be conveniently conducted within small confines. It should be noted that more prior training and practice will be required than was used in this study, so that decrements in performance due to environmental stress will not be offset by the effects of developing skill.

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Figure Captions

Figure 1. Group mean response times for each target position at each viewing distance.

Figure 2. Group mean response times for each target at each viewing distance.

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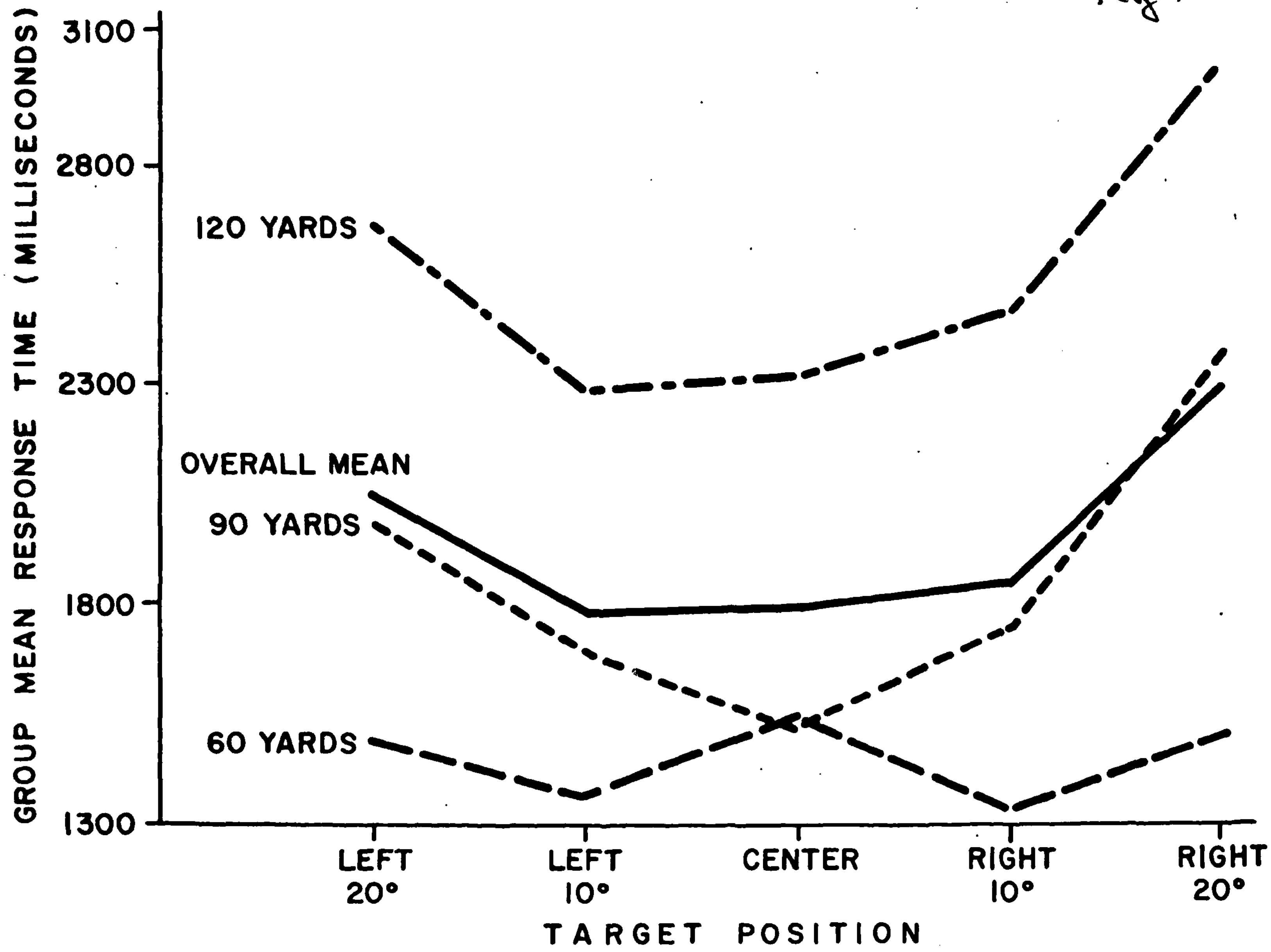
Abstract

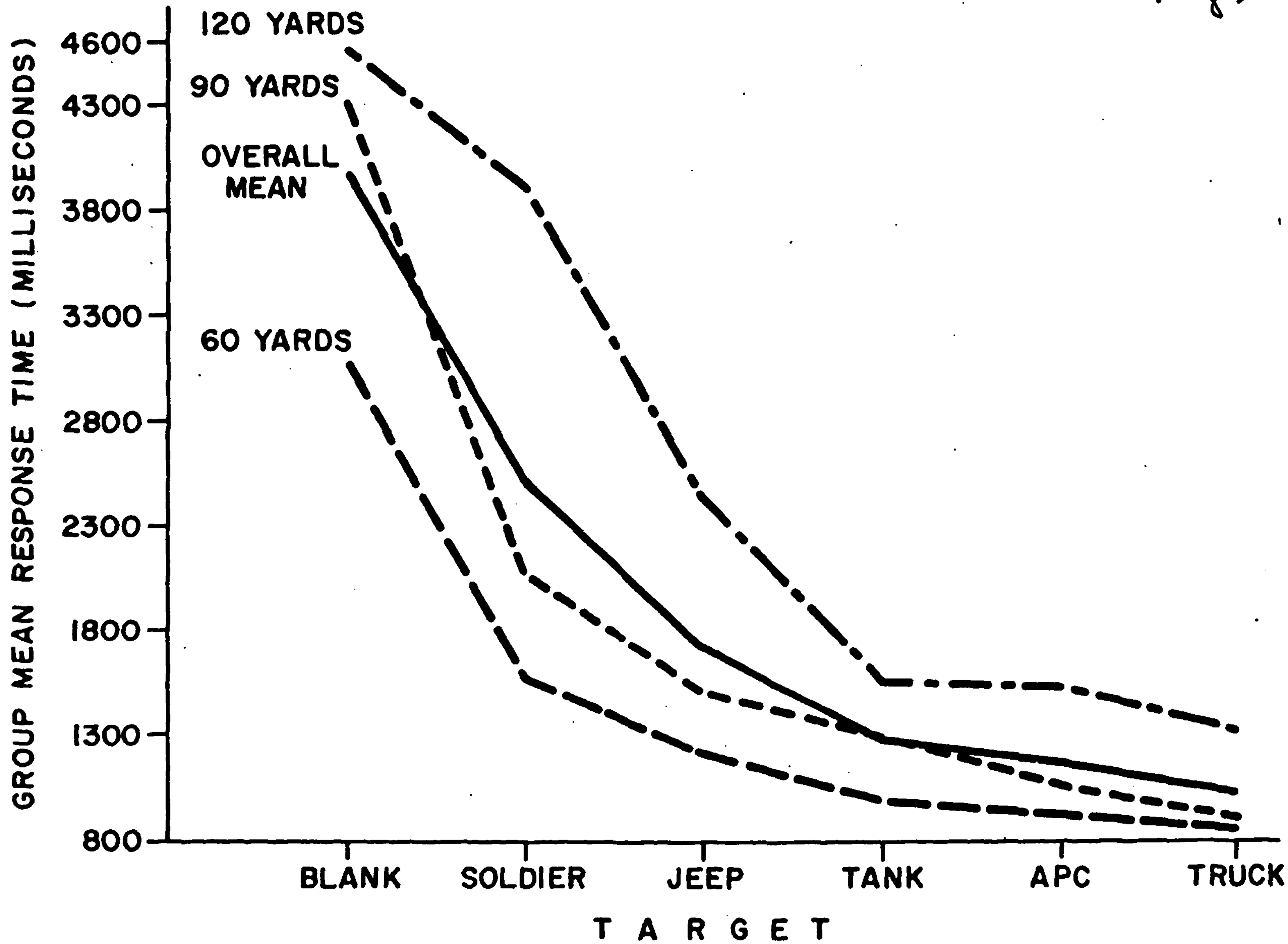
The influence of target size, peripheral target position, and viewing distance on target detection and identification was studied. Thirteen normally-sighted males were trained, and then replicated seven complete task performances. The main effects of target size, target position, and viewing distance were all highly significant, as were the involved simple and second-order interactions ($P < .001$). Both viewing distance and target size significantly influenced target detection, in inverse relation to the effective size of the stimulus, such that reduced image size at the eye was associated with longer target detection time. The degree of peripheral target location was universally associated with longer detection time for all target sizes, indicating that search performance was strongly oriented to the center of the field of view, rather than to the periphery. This corroborates previous findings regarding central-peripheral response time relationships. This study is unusual in combining laboratory control of stimulus and viewing conditions with the use of realistic target objects usually obtainable only in field studies.

Fig 1



GROUP MEAN RESPONSE TIME (MILLISECONDS)
3100
2800
2300
1800
1300
120 YARDS
OVERALL MEAN
90 YARDS
60 YARDS
LEFT 20°
LEFT 10°
CENTER
RIGHT 10°
RIGHT 20°
TARGET POSITION

Fig 2


120 YARDS
90 YARDS
OVERALL MEAN
60 YARDS
GROUP MEAN RESPONSE TIME (MILLISECONDS)
4600
4300
3800
3300
2800
2300
1800
1300
800
BLANK
SOLDIER
JEEP
TANK
APC
TRUCK
T A R G E T

1. The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

2. Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.